

Surface Finish Issues Affecting Solderability and Reliability

ACI Technologies was contacted in regards to poor solder joint reliability. The customer submitted an assembly that was exhibiting intermittent opens at multiple locations on a ball grid array (BGA) component. The assembly's functionality did not survive international shipping, essentially shock and vibration failures, immediately making the quality of the solder joints suspect. The customer was asked about the contract manufacturer and the reflow oven profile as well as the solder paste and surface finish used. The ACI engineering staff evaluated the contract manufacturer's technique and determined that they were competent in the methods they used for placing thermocouples in the proper locations and developing the reflow oven profile. The surface finish was unusual, but not unheard of, in that it was hard gold over hard nickel, rather than electroless nickel immersion gold (ENIG). The customer was able to supply boundary scan testing data which showed a diagonal row of troublesome BGA pins.

The ACI analytical services staff determined that cross-sectional analysis with optical microscopy and scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDS) would provide the best information as to what had happened. The focus of the microsectioning was through the diagonal row of the BGA pins indicated by the boundary scan data.

A position halfway through the BGA solder balls along a diagonal through the BGA component was selected as the area of interest to examine the solder joints, surface plating, and foil thickness as well as any anomalies from internal observations. The microsectioning was performed in accordance with IPC-TM-650 2.1.1 - Microsectioning, Manual Method. In Figure 1, images of one of the suspect solder joints are shown with a clean break along the board pad to solder ball interface.

After examining similar solder joint cracks under optical microscopy, the cross-section was analyzed using SEM-EDS. Figure 2 shows the pad interface of the cracked joint of an outer BGA solder ball in which nickel (Ni) was predominant with a minor contribution of tin (Sn). Figure 3 shows the solder ball interface of the same cracked joint of an outer BGA solder ball with copper (Cu) from the SAC (Sn-Ag-Cu) solder paste, nickel (Ni) from the pad, gold (Au) from the pad, and tin-silver (Sn-Ag) from the solder ball.

The low levels of gold observed at the interface, especially with no line of demarcation, and few intermetallics at the pad interface (with the hard gold over hard nickel plating) suggested that there was an issue with the bare board. Oxidation of the nickel plating, either during the surface finish deposition or through an insufficient layer of gold, could prevent solder from adhering to the pad to form a strong solder joint. The patchy intermetallic layer observed at the interface also suggested a blocking of the nickel interface.

The clean breaks at the nickel layer of some of the BGA solder joints, especially from the outside towards the inside of the component,

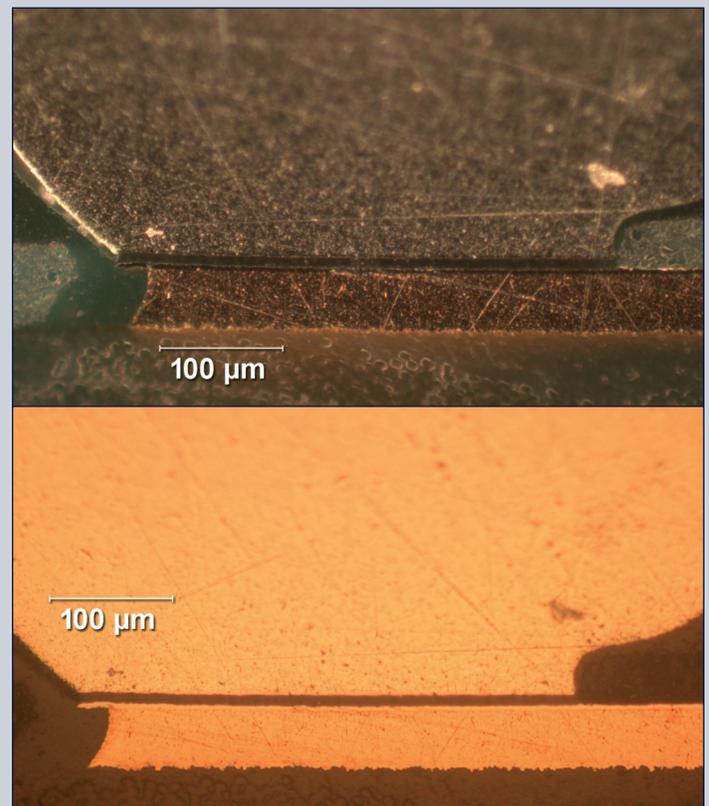


Figure 1: Optical images of a broken solder joint along the board pad to solder ball interface. Dark field image on top; bright field image below.

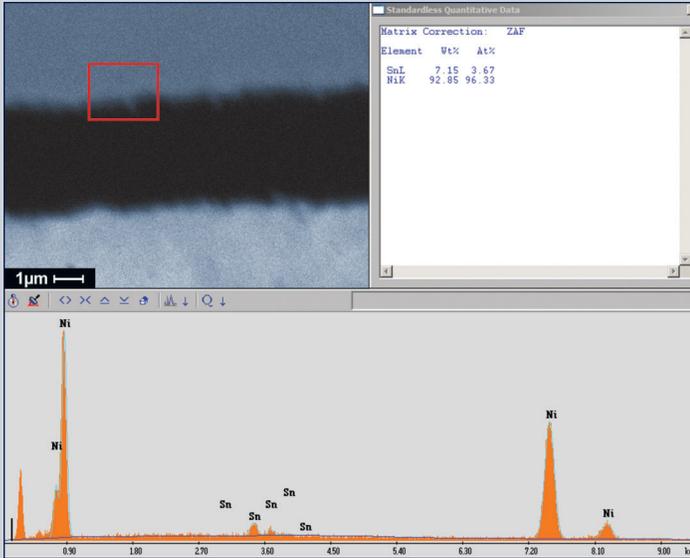


Figure 2: SEM-EDS data for the pad side of an outer solder joint that cracked.

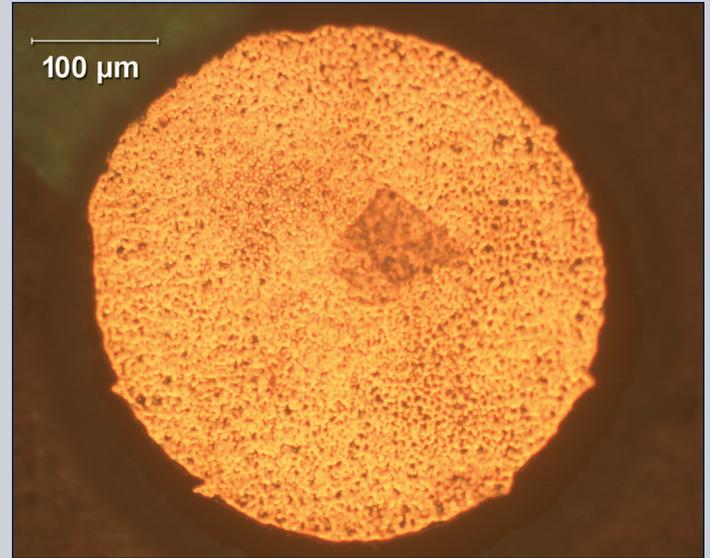


Figure 4: Optical image of the rough surface of a pad.

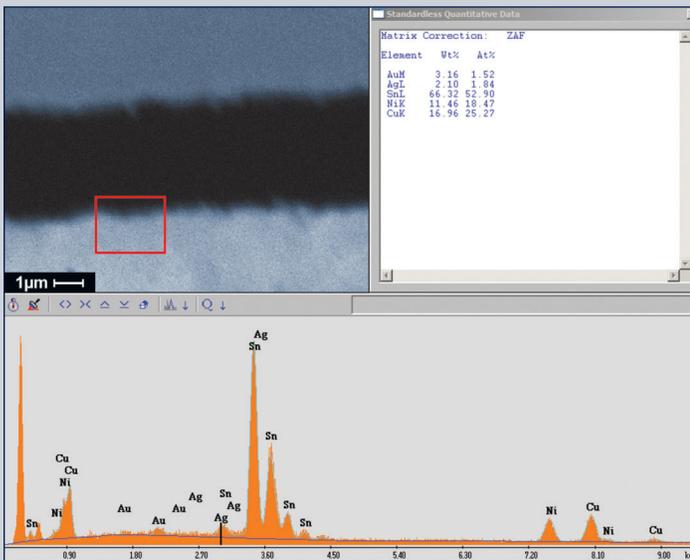


Figure 3: SEM-EDS data for the solder ball side of an outer solder joint that cracked.

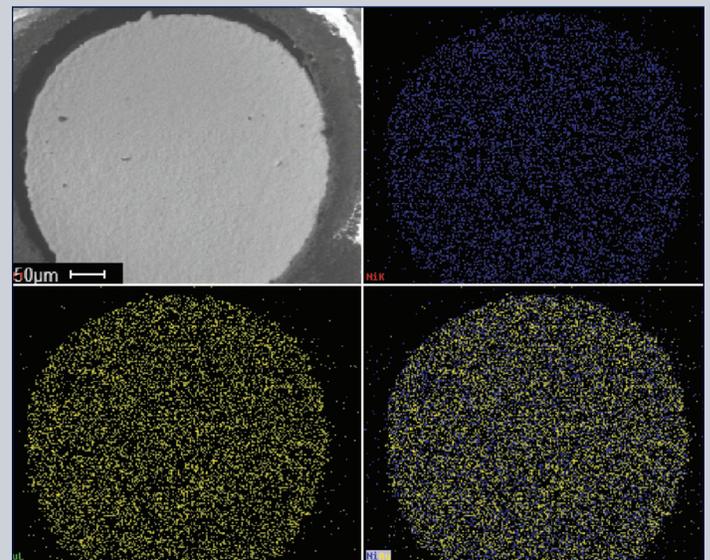


Figure 5: SEM-EDS elemental map of a pad. [Top left - image, top right - nickel (blue), bottom left - gold (yellow), bottom right - overlay of both.] The overlay map shows patches where the nickel may be exposed through the gold.

indicated that it was less likely the assembly manufacturing process was the cause and more likely the bare board. During the reflow process, the corners of the component are the hottest and the center should be coldest. The center would most likely fail if the process was too cold while dewetting and excessive intermetallics would be observed if the process was too hot. This points to surface finish as the likely problem since low intermetallic formation was observed and the solder joints weren't broken near the center of the BGA.

ACI recommended evaluating the plating process of the bare board and the hard gold over hard nickel surface finish to see if they met the recommended thicknesses for the nickel and especially the gold layers. Also, removal of any storage or processing step that would have led to the oxidation or fouling of the nickel surface should increase the solder joint reliability.

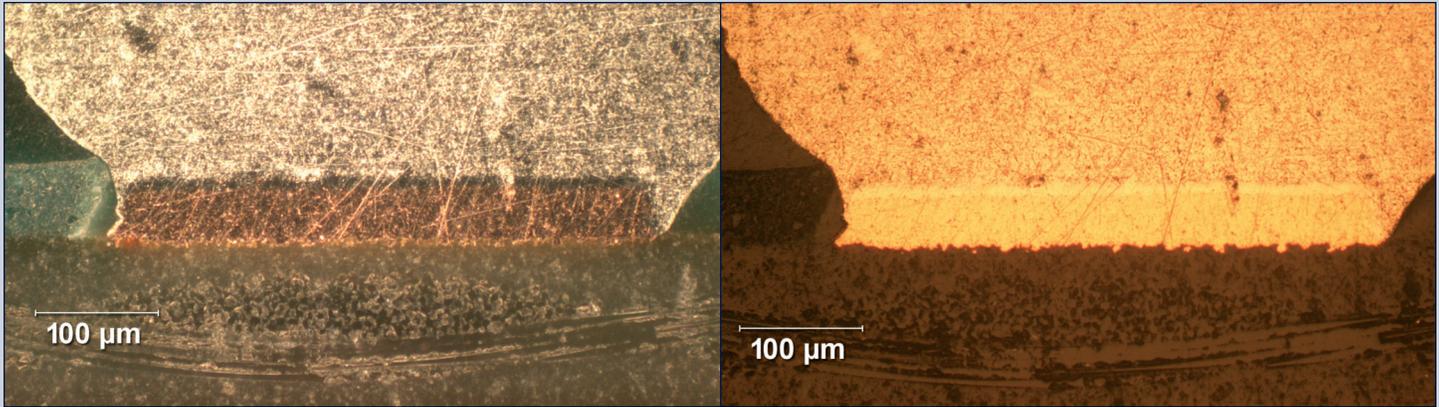


Figure 6: Optical image of a good solder joint along the board pad to solder ball interface. Dark field image on left; bright field image on right.

Optical microscopy, X-ray fluorescence (XRF) spectroscopy, and/or SEM-EDS techniques were recommended to determine the plating thickness and porosity. The customer was able to provide a bare board from a similar lot to the previously examined assembly. Figure 4 shows the uneven and apparently porous gold surface of a representative BGA pad location. Figure 5 shows the SEM-EDS elemental mapping for a BGA pad where nickel appears to be visible through thin patches of the gold plating.

Optical microscopy showed uneven gold plating on the pads throughout the board. The SEM-EDS data also showed patchy gold plating with nickel apparently being exposed through the gold. All of this data indicates that the process producing these boards was not properly controlled.

ACI recommended that the customer speak with their bare board manufacturer about improving the hard gold over hard nickel plating process or switching to other surface finishes, such as soft gold over nickel plating, electroless nickel immersion gold (ENIG), or immersion silver (IAG).

The customer made a new set of boards with an IAG surface finish and provided them to ACI in the bare board and finished assembly states. Figure 6 shows images of a representative solder joint in which good bonding along the board pad to solder ball interface was observed.

ACI recommended that the customer perform incoming quality acceptance inspections on PCBs as part of their supplier quality control strategy until such time that the supplier has proved capable of providing material acceptable to the appropriate requirements. The acceptance testing should include solderability testing, non-destructive plating thickness measurement, and visual workmanship

assessment to ensure compliance to the requirements of IPC-6012 - Qualification and Performance Specification for Rigid Printed Boards and IPC-A-600 - Acceptability of Printed Boards. Failure to meet these requirements should be used as justification to reject individual PCBs and/or entire board lots, as necessary.

Additionally, the supplier should also perform inspections to ensure that nonconforming material is not provided to customer. The customer's drawings should place requirements on their supplier(s) by providing notes that use language similar to the following:

- Manufacture in conformance with the requirements of IPC-6012 (latest revision), Class [1, 2, or 3, as appropriate].
- Inspect per the requirements of IPC-A-600 (latest revision), Class [1, 2, or 3, as appropriate].

ACI can provide board and assembly qualifications, and inspections, as well as failure analysis to determine the root cause of solder joint failures. ACI can further assist with surface finish analysis, cleaning processes and cleanliness testing for ionic and organic residues, and engineering services. Ion chromatography, bulk ionics (Ionograph) testing, attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy, X-ray fluorescence (XRF) spectroscopy, and ultraviolet/visible (UV-Vis) spectroscopy, optical microscopy, and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS) capabilities are all on hand to aid in the determination of possible contamination issues and their root causes. Contact ACI by calling 610.362.1320, emailing helpline@aciusa.org or visiting the website at www.aciusa.org.

ACI Technologies



ACI Technologies, Inc. 1 International Plaza, Suite 600 Philadelphia, PA 19113 phone: 610.362.1200 web: www.aciusa.org

Training Center phone: 610.362.1295 email: registrar@aciusa.org

Helpline phone: 610.362.1320 email: helpline@aciusa.org